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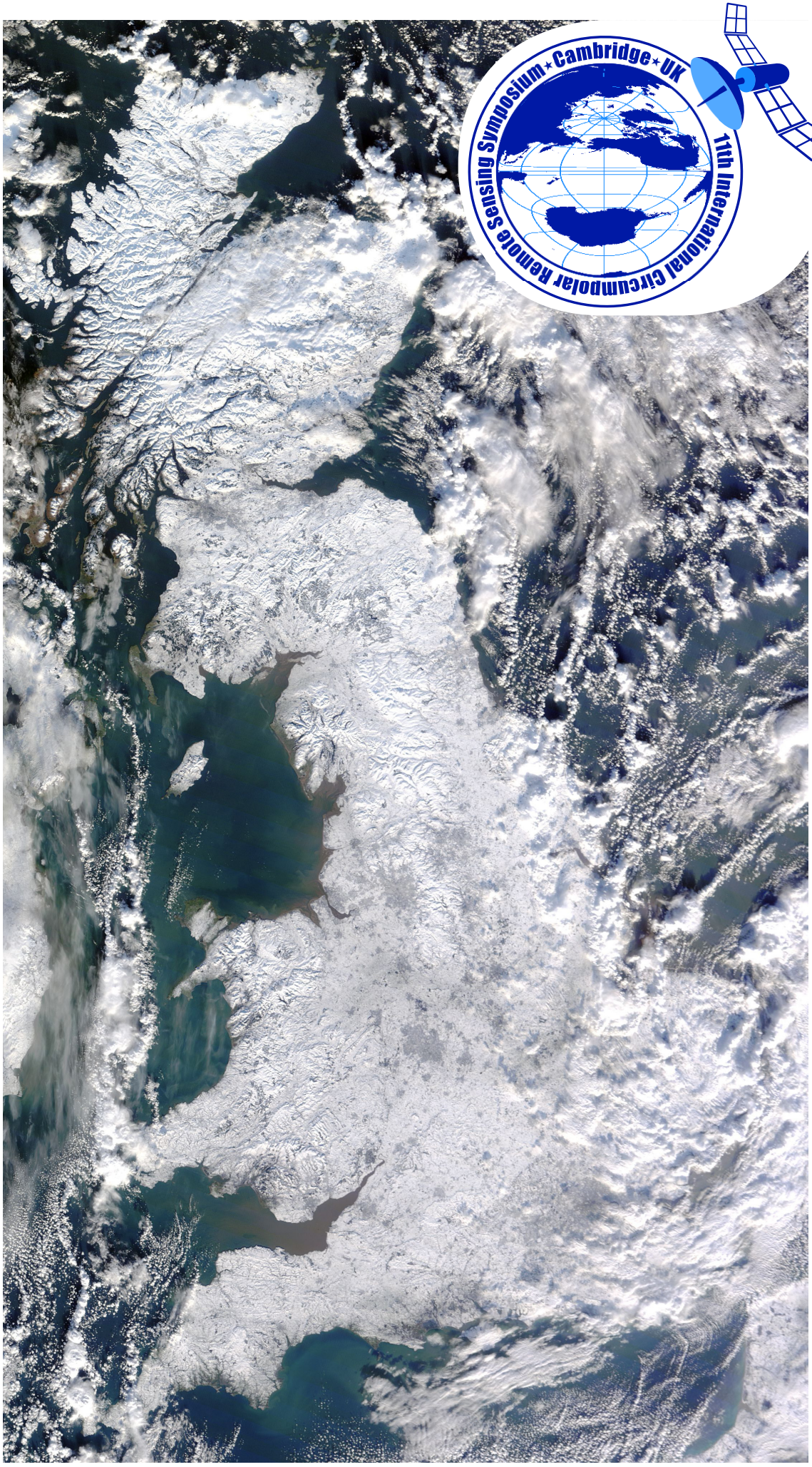

NASA Image by Jeff Schmaltz, MODIS Rapid Response Team, Goddard Space Flight Center. 01.07.2010.

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Ten years of SeaWinds QuikScat for circumpolar snow monitoring

A. Bartsch
Institute of Photogrammetry and Remote Sensing, Vienna University of Technology, Gusshausstrasse 27-29, 1040 Vienna, Austria; annett.bartsch@tuwien.ac.at

For 10 years (1999-2009) the SeaWinds instrument on board of QuikScat provided a 90% global daily coverage. Apart from its mission objective to support ocean-meteorological studies, it has been also used for land applications. As it has been operating in Ku-Band it has been mostly applied to snow applications but also for monitoring vegetation phenology, urban mapping and soil moisture. The majority of developed algorithms are change detection methods. Some exploit the availability of multiple daily measurements at high latitudes (up to 10 towards 75°N). The high temporal frequency was a rather unique feature among contemporaneously operating scatterometer.

This paper reviews applications such as detection of snowmelt timing as well as mid-winter thaw and refreeze. Short term thawing of the snow surface and subsequent refreeze can lead to the formation of ice crusts. These events are related to specific meteorological conditions such as rain-on-snow events and/or temporary increase of air temperature above zero degree Celsius. The structure change in the snow pack has adverse effect especially on wild life and also the local community related to reindeer herding.

A multi-satellite concept in support of high latitude permafrost modeling and monitoring - The ESA DUE Permafrost project

A. Bartsch[1], F. M. Seifert[2], & the ESA DUE Permafrost Team

1) Institute of Photogrammetry and Remote Sensing, Vienna University of Technology, Gusshausstrasse 27-29, 1040 Vienna, Austria; annett.bartsch@tuwien.ac.at

2) European Space Agency, ESRIN, Frascati, Italy

A number of remotely sensed products have been developed in the past which provide information relevant to permafrost distribution on circumpolar scale. They comprise parameters such as land surface temperature, land cover, soil moisture, disturbances, snow, terrain and methane. A monitoring system of high latitude permafrost requires regular and multiscale observation of all these parameters. Further on, the datasets need to meet requirements of permafrost models as well as support related research in geomorphology, botany and hydrology.

Such a comprehensive database is setup within the framework of the European Space Agency's (ESA) Data User Element (DUE) program. The ESA DUE Permafrost project establishes a monitoring system on local to pan-boreal/arctic scale based on satellite data. Within this project permafrost relevant remotely sensed products are assessed and eventually provided to users. The complexity of the phenomenon permafrost requires the close cooperation with the scientific community working in this field.
The consortium is led by I.P.F, Vienna University of Technology and supported by four partners: Gamma Remote Sensing, University of Waterloo, Friedrich Schiller University Jena and the Alfred Wegener Institute for Polar and Marine Research.

Permafrost is a subsurface phenomenon and cannot be directly observed with satellite data. Yet, monitoring can be done based on indicators and via permafrost models. Indicators are especially thermokarst lake dynamics and surface elevation changes. Those phenomena need to be observed on a local scale. Regional to circumpolar monitoring requires the use of permafrost models for which the following dataset will be provided:
Land surface temperature is available from passive sensors such as MODIS, AATSR, and AMSR-E. It can be used as a forcing parameter for all permafrost models.

The amount of snow determines insulation properties. An operational monitoring service for snow extent and SWE is currently being set up within the ESA DUE project GlobSnow.

Vegetation layer also insulates the ground. A number of global and regional land cover maps are available (e.g. from GlobCover). They need to be merged and assessed for the purpose of modelling of permafrost and fluxes.

Thermal conductivity is influenced by soil moisture. A near real-time (NRT) product based on METOP ASCAT is available from EUMETSAT. This service will be improved within the project under the viewpoint of frozen ground conditions.

The circumpolar datasets will be provided weekly to monthly with a spatial resolution of 25 km x 25 km. Selected areas will also be monitored at 1 km x 1 km for snow extent (SE), LST, soil moisture, and vegetation. High resolution satellite data are used at selected local sites. All satellite data products will eventually be made freely available via a WebGIS.

Further Information: www.ipf.tuwien.ac.at/permafrost

Topographic Data Acquisition In Canada's Arctic With RADARSAT-2 Imagery

Daniel Clavet
Centre for Topographic Information
Natural Resources Canada, Government of Canada
2144 King Street West, Sherbrooke, Quebec, Canada. J1J 2E8
dclavet@NRCan.gc.ca

Canada holds a very large part of the Northern hemisphere and, with a small sparsely distributed population, Canada faces challenges to ensure provision of quality geospatial information. Natural Resources Canada is playing a key role in providing such information for Nunavut, Northwest Territories and Yukon. To do so, NRCan has developed an innovative process to extract from Radarsat-2 imagery, vector topographic data (Canvec) and DEM data (CDED) at the scale of 1:50,000 in the Arctic.

Results from a feasibility project conducted on two test sites in the Arctic indicate that planimetric and altimetric accuracies meet topographic mapping requirements at scales of 1:50,000.Feature content assessment indicates that glaciers, glacial features (moraines, eskers), and hydrographic features meet the required detail level with very few omissions. Topographic feature extraction is performed in 3D from a stereo pair of Radarsat-2 images in Ultra-Fine mode, with same side incidence angles between 37 degrees and 49 degrees. DEM extraction is also performed on stereo pairs; auto-correlation and manual collection approaches are compared.

The production of 38 topographic data sets is planned above the 81st degree Latitude North. The image acquisition plan, contract requirements, topographic feature acquisition specifications and data validation procedures are presented. Image acquisition is planned for August, data preparation and contracting out is planned for September 2010.

This presentation will bring forward advantages of utilizing Radarsat-2 imagery and the limitations created by local topography, image acquisition conflicts and image acquisition dates. Human resource training and technology transfer will also be discussed.

Reindeer pasture changes in northern Finland 1995 - 2005.

Alfred Colpaert
University of Eastern Finland, Joensuu Campus
Department of Geographical and Historical Studies
BOX 111
80101 Joensuu
Finland
Alfred.colpaert@uef.fi

Jouko Kumpula
Finnish Game and Fisheries Institute, Reindeer research
Kaamanan, Finland

The pastures in the Finnish reindeer management area have been monitored since 1995 using remote sensing and field inventory. The first inventory was made in 1995-96, updated in the beginning of 2000's and repeated in 2005-08. By comparing results from 1995-96 and 2005-2008 we can observe clear changes in forest cover and lichen pastures. Changes in spatial extent of pasture units are not always easy to compare as direction of error can vary in pixel wise comparison.

There are many reasons for this; changes in remote sensing platform, changes in processing software and methodology, changes in field methods and ancillary data, and obviously also bias introduced by differences between analyst. We have also noted that differences in lichen moisture content produces spectral and morphological changes which influence both classification of lichen pastures and the estimated lichen biomass. To overcome the last problem we have introduced moisture content into our volumetric biomass equation.

To evaluate pasture/vegetation changes on the basis of separate classifications we have used a grid approach. By implementing a 500 by 500 meter grid network and summarizing pastures classes for every grid cell we can visualize and quantify intensity of change. For pixel wise evaluation of two classifications with accuracy of 80 % we would produce a change mosaic having a lower accuracy, which is not very satisfying. By summarizing all classes in a 500 meter grid cell we can use decision rules to reclassify each cell into a pasture class. In this way random effects of pixel error can be filtered out. For example we used a rule of 40 %, i.e. ten hectares or over out of 25, to classify a cell as being mature or old growth pine dominated. By comparing 1995-96 and 2005-2008 we can see a change from 71,000 cells to 57,197, a decline of 19 %. This of course does not mean an exact figure for decline in old growth forest of 19 %, but indicates a significant change in forest structure, fragmentation and reduction reindeer winter pasture value in large areas.

When comparing reindeer lichen biomass between 1995-96 and 2005-08 on the basis of field site data, lichen biomass has declined in 19 out of the 20 reindeer management districts. Only one district showed slight improvement, in three districts there was a significant drop in lichen biomass, from over 1500 kg/ha to about 500 kg/ha. Also amount of arboreal lichens declined markedly due to felling of old growth forest, confirming the findings on the grid cell level. Consequently grass, shrub and sapling stands increased as felled areas start to grow graminoids and herbs. Dividing pasture areas into separate winter and summer pastures using fences, as some herding districts have done, clearly seems to preserve ground lichen pastures in better condition as there were significantly more lichens in winter than in summer pastures in those districts using this practice.

Assessment and prediction of reindeer habitat in northern Europe

Fiona Danks[1] and Gareth Rees[2]
1) Norwegian Polar Institute
2) Scott Polar Research Institute

We investigate the relationship between the spatial scale of vegetation analysis and its suitability for assessment of reindeer pasture and habitat in northern Europe, especially in response to climate change. The most suitable scale is represented by Landsat or similar satellite imagery, although long-term monitoring is currently restricted to coarser scales. By combining data on the current distribution of reindeer in northern Europe with the output of climate and ecosystem models, we consider the vulnerability of reindeer husbandry to climate change to the year 2080.

Recent Eruptions of Arctic Volcanoes and their Impact

Ken Dean, Peter Webley, Jon Dehn, Scott Macfarlane and Torge Steensen

Geophysical Institute/Alaska Volcano Observatory, University of Alaska Fairbanks 903 Koyukuk Drive, Fairbanks, Alaska 99775-7320

Email: kdean@gi.alaska.edu

In recent years, there have been six significant eruptions from Northern Latitude/Arctic volcanoes that impacted large expanses and even areas beyond the arctic region. These volcanoes are: Mount Augustine (2006, Alaska, USA), Okmok (2008, Alaska, USA), Kasatochi (2008, Alaska, USA) Redoubt (2009, Alaska, USA), Sarychev (2009, Kamchatka, Russia), and Eyjafjallajökull (2010-ongoing, Iceland). All of the eruptions were explosive in nature and resulted in volcanic ash seriously impacting numerous airports in Alaska and Europe, and northern polar air routes. Airborne volcanic ash and sulfur dioxide can be detected on data recorded by satellite sensors with up to hourly coverage, such as AVHRR, MODIS, GOES, Meteosat, AIRS and OMI. However, satellite sensor detection of these clouds is not consistent and depends upon orbital parameters, solar illumination, weather conditions and environmental conditions. Also, the movement of these clouds can be predicted using dispersion models such as Puff, HYSPLIT and MLDPO or other more comprehensive eruption models, such as NAME at the London Advisory Centre for Europe. However, these models tend to over-predict particle distribution in distal areas. The most serious problem not fully addressed is qualitative prediction of absolute airborne ash concentration and identification or definition of dangerous levels of ash concentration. It is the high levels of ash concentration and prolonged exposure that can cause aircraft engine failure, health problems and disrupt our transportation infrastructure. We have been researching the potential of using multi-temporal satellite data composites with dispersion model predictions to define more stringent boundaries based on relative levels of ash concentration; Highest, Moderate and Lowest. This analysis would become the foundation for a hazard assessment map that can be processed in near-real time to assist in hazard responses during an eruption. Later by incorporating volcanic ash retrievals and other field/ground measurements we aim to define these limits with some qualitative levels.

Detecting Vegetation Changes in Tundra using 25-year Landsat Image Stacks

Robert Fraser, Ian Olthof, Mélanie Carrière, and Alice Deschamps

Canada Center for Remote Sensing, Natural Resources Canada
588 Booth St., Ottawa, ON, K1A 0Y7
Tel: (613) 947-6613 / Fax: (613) 947-1385
Robert.Fraser@NRCan.gc.ca

Remote sensing has provided evidence of vegetation changes in Arctic tundra that may be attributable to recent climate warming. These changes are evident from local scales as expanding shrub cover observed in aerial photos to continental scales as a greening trends based on satellite vegetation indices. One challenge in applying conventional two-date change detection in tundra environments using medium resolution (~ 30-m) imagery is the high interannual variability in vegetation growth, combined with a short growing season observation window. An alternative change approach is to create dense stacks of time series imagery that are analyzed for long-term reflectance trends. The freely accessible Landsat satellite archive provides a cost-effective means of developing stacks of 30-m multispectral imagery for the period since 1984. We created Landsat image stacks composed of 20-25 growing season scenes for five Canadian Arctic and sub-Arctic parks (Ivvavik and Tombstone in Yukon, Wapusk in NE Manitoba, Torngat Mountains in Labrador, and Sirmilik by N Baffin Island). The NDVI and Tasselled Cap Brightness, Greenness, and Wetness indices were analyzed for per-pixel linear trends using robust regression. Trends were then summarized by both park-specific ecosystem types and general land cover classes common to all parks to reveal any consistent patterns. The indices were further related to long-term change in fractional shrub and other vegetation covers using a regression tree classifier trained with 2-4 m resolution land cover. The results suggest a strong trend towards greening and fractional shrub increase in Ivvavik's coastal plain and nearby Herschel Island, and in lower valleys throughout the Torngat Mountains. The majority of glaciers on Sirmilik's Bylot Island were observed to have receding margins, some shrinking at a rate of 30m/yr. Wapusk demonstrated a wide range of trends related to wildfire, shallow water bodies, and damage to coastal wetland vegetation from increasing snow geese populations. Tombstone, containing alpine tundra, showed a NDVI decrease for non-vascular vegetation types (lichen and moss) and impacts at lower elevations related to wildfire and open pit mining. Overall, the image stack analysis approach was effective in documenting long-term changes in tundra environments caused both by climate warming and disturbance. Parks Canada Agency, our partner for this work, plans to adopt these methods for monitoring and reporting on ecological integrity in Arctic National Parks.

Estimating emperor penguin (Aptenodytes forsteri) distribution and population from satellite imagery.

Fretwell, P.T., Morin, P., LaRue, M.A., Kooyman, G.L, Wienecke, B., Porter, C., Fox, A.J., Ponganis, P.J., Fleming, A., Brolsma, H., Trathan, P.N.

The emperor penguin (Aptenodytes forsteri) is a species that is poorly mapped, in large part due to its unique breeding habits and the difficulty in accessing its breeding habitat. Recent work by Fretwell and Trathan (2009) used Landsat ETM imagery to map the distribution of the species, finding 38 colonies of which 10 were previously unknown. This study highlighted the fact that no reliable population estimate of the species exists.

Here we present details of new work building on the previous study. We have acquired Quickbird2 images of every colony, between October and December 2009; one breeding season. Using this sub-metre resolution imagery we have: checked locations not included in the previous survey, confirmed the previous Landsat findings and estimated the breeding population of the species. Improving on the method of Barber-Meyer et al.(2007), and using previously acquired ground truthing, we have analyzed each image using Supervised Multivariate Classification Analysis to assess the population at each site.

Here we present some initial findings from the study:

There are 44 emperor penguin colonies, 17 of which are have been newly found by satellite in this or the previous landsat study, thus increasing the number of known emperor penguin colonies by 60%.
A new distribution map for emperor penguins.
A new global breeding population estimate for the species.

The main focus of this paper will be to discuss the statistical accuracy of the method and examine the meaning and relevance of this “snap-shot” of emperor penguin numbers taking into account daily, seasonal and yearly variability at emperor colonies.

Finally we discuss future work using remote sensing to examine colony and cluster size, local habitat and behaviour at individual breeding sites.

Evaluating the Austre Lovénbreen (Svalbard) glacier ice volume, area and its bedrock topography using Ground Penetrating Radar and differential GPS measurements.

Jean-Michel FRIEDT (1), Dominique LAFFLY (2), Albane SAINTENOY (3), Eric BERNARD (4), Madeleine GRISELIN (4), Christelle MARLIN (3)

1. Université de Franche-Comté, laboratoire THÉMA UMR 6049 CNRS, 2. Université de Toulouse, laboratoire GEODE UMR 5602 CNRS, 3. Université de Franche-Comté, laboratoire FEMTO-ST UMR 6174 CNRS, 4. Université de Paris-sud Orsay, laboratoire IDES UMR 8148 CNRS

Polar glacier volume and area evolution is a central topic of the Hydro-Sensor-FlOWS program (IPY #16). Past Digital Elevation Model (DEM) data provide a basic dataset for estimating the time evolution of the glacier area. However, a major issue appears to be the different map projections used over time, and converting each projection to a common format with an accuracy compatible with area estimate.

Glacier volume is an immediate indicator of climatic impact on the cryosphere, while glacier area is affected with a time delay of several years, dependent on glacier front contact angle. Hence, the volume variation of the glacier is the actual indicator of long term and short term evolution of the glacier behaviour.

To define the volume evolution of the Austre Lovénbreen for the last 40 years, we used a map of 1966, the DEM established by NPI in 1995 and our DGPS tracks of 2010.

We presented first results in Whitehorse (2008) with a comparison of DEM 1995 and Spirit DEM 2007. In the present paper, by improving the data processing strategy and due to a very accurate cover of the glacier with DGPS, we can improve the accuracy of our estimation of volume loss.

We will discuss here the challenges in comparing different “historic” document, maps and DEM, originally provided with different projections (UTM zone 33, European Datum 1950). Data of the oldest maps have been converted to UTM 33 - WGS 84 through ERDAS software. We attempt to estimate our error bar concerning the altitude evaluation, by assessing both geometric model errors during projection conversions, and instrument accuracy.

We complement the volume loss with the total volume of the glacier as measured in April 2010 thanks to a Ground Penetrating Radar (GPR) field survey.

The historic DEM were updated at the same time using DGPS measurements: a dense elevation mapping was performed and projected on the same common DEM model to estimate surface elevation evolution with respect to the historic DEM, and used as reference for the altitude correction during GPR data processing. The resulting maps indicate that the Austre Lovénbreen is 160 m deep, and that while shrinking area has been most significant from 1970 to 1990, volume reduction has become predominant since 1990 and up to now.

The resulting digital elevation model of the bedrock, and the associated glacier volume estimate in the 0.359+/-0.005 km3 range, are presented as results of this study.

We will discuss the limits of such investigation when we compare the DEM 2007 and DGPS 2010 difference, and the consistency of the result with our on-site measurements performed on 42 accumulation/ablation stakes anchored in the ice. We observe that the elevation

model error is too large to allow for a volume evolution measurement on such a short period (3 years), while the volume loss becomes significant with respect to the error bar over a longer time scale (40 years).

Vegetation mapping of Svalbard, Arctic Norway, utilizing Landsat TM/ETM+ data

Bernt Johansen (Senior Researcher), Hans Tømmervik, Stein Rune Karlsen, and Arve Elvebakk
bernt.johansen@norut.no
Phone +47 91168927
Northern Research Institute Tromsø (Norut)
P.O.Box. N-9294 Tromsø, Norway

The overall objective of this presentation is to discuss and validate the most recently developed vegetation map for Svalbard, Arctic Norway. During the project a generalized, seamless and consistent vegetation map is developed portraying the entire Svalbard archipelago. The map is based on satellite images where several Landsat TM/ETM+ images are processed through six operational stages involving: (1) automatic image classification, (2) spectral similarity analysis, (3) generation of classified image mosaics, (4) ancillary data analysis, (5) contextual correction, and (6) standardization of the final map products. The three first stages in this process is denoted the pre-classification process, whereas the post-classification process (stage 4,5) involves the integration of different types of ancillary data. In the final standardization stage (6) the separated classes were related to map schemes valid for the mapping area.

The developed map is differentiated into 18 map units interpreted from 37 spectral classes. Among the separated units rivers, inland waters, glaciers, and non- to sparsely vegetated areas constitute six of the entities. The map unit number seven is a result of shade effects from steep mountains and different types of distortions in the satellite images. The vegetation of the remaining units varies from dense marshes and moss tundra community types to sparsely vegetated polar deserts and moist, gravel snowbeds. The accuracy of the map is evaluated in areas were access to traditional maps have been available. The map product is in digital format, which gives an opportunity to produce maps in different scales. A map sheet portraying the entire archipelago is produced in scale 1:500 000. A sub-section of the map portraying Nordenskiöld Land is produced in scale 1:100 000.

Arctic areas are generally one-layered and classifications performed on such vegetation directly portrays the vegetation communities and landscape features. By drawing spectral patterns for dominant vegetation classes, important characteristics are detected. Snow and glaciers show extremely high reflectance values in the visible and in the NIR part of the spectrum with low MIR values indicating wet site conditions. Classes associated to open water show highest values in the visible blue, combined with spectral absorption in the MIR channels. Further vegetation communities associated to wet and moist growing sites show lowered MIR reflectance, while classes on dry, exposed sites are characterized by high MIR reflectance. The fertility and density of the vegetation cover is mainly reflected in the NIR part of the spectrum. By drawing gradient in different directions from south to north, from west to east and from lowland to mountain areas, the variance in occurrence of vegetation communities are to be deduced. The most favourable areas for vegetation growth are found in the inner fjord zone of the Isfjord region. The largest glaciers are found in northeast. Areas bounding the glaciers are poorly developed, constituting the polar deserts vegetation zone.

MODIS based mapping of the growing season on Svalbard

Stein Rune Karlsen (Senior Researcher, PhD), Kjell-Arild Høgda, and Bernt Johansen
stein-rune.karlsen@norut.no, kjell-arild.hoegda@norut.no, bernt.johansen@norut.no
Phone +47 93419904
Northern Research Institute Tromsø (Norut)
P.O.Box. N-9294 Tromsø, Norway

Changes in the timing of the growing season are among the most sensitive bio-indicators of climate change. The aim of this study is to use MODIS data to map onset, end, and length of the growing season on Svalbard for the 2000 to 2009 period.

Phenological field observations along tracks close to the village Longyearbyen and close to the research station Ny-Ålesund has been established. These tracks were designed to detect the phenological variation at a scale that can be compared with MODIS data, as they capture the spatial and temporal variation in onset and end dates covering an area of about 15 km2 and 2 km2, respectively. The onset and end of the growing season is defined as flowering catkins and colouring of leaves of the small willow Salix polaris, respectively.

We used MODIS data for the 2000 to 2009 period, both the MOD09A1 product (8-days, 500m, 7-bands reflectance) and the MOD09Q1 product (8-days, 250m, red and NIR reflectance). First we used the MOD09A1 product and studied the spectral properties of different vegetation types during the growing season, this to identify which bands that best monitor the onset and end of the growing season. Then we calculated NDVI based on the MOD09Q1 product and other indices based on other band combinations from the MOD09A1 product.

In the calibration process, first every 8-day period in the MOD09A1 product were visually inspected for clouds. The noisiest 8-day periods were then replaced with mean values from the periods before and after. Then, the NDVI and other indices curves were smoothed with the TIMESAT program. Finally, a new combined pixel-specific threshold and decision rule-based mapping method was used to determine the onset and end of the growing season. In spring, NDVI showed best correlation with field data. In autumn, indices based on combination of a band in the visible part with a band in the short-wave infrared part showed best correlation with field observations, however with a bias of about 2 weeks too late.

The results show large variations in the onset of growing season from year-to-year during the 2000 to 2009 period. In some fjords, and on the northeast coast, the onset of the growing season corresponds with the timing of the melting sea-ice. In autumn two years could not be mapped due to too long periods with clouds or fog, and for the remaining years the results show only small variations among the years. The resulting phenological maps can be used in a broad range of ecological and climate change studies.

The project is a part of an ongoing Environmental monitoring system for Svalbard and Jan Mayen (MOSJ). In MOSJ Norut also contribute with snow cover monitoring based on combined MODIS and ASAR data, and have processed a time-series of NDVI data with 1 km resolution for the 1986-2009 period based on the NOAA-AVHRR satellite series.

Oral Presentation, Vegetation

Evaluation of oil and gas industry disturbance on tundra vegetation detected from satellite imagery time series

Kumpula T[1](presenter), & B.C. Forbes[2]

1 Department of Geography and history, University of Eastern Finland, Yliopistonkatu 7, 80101 Joensuu, Finland; timo.kumpula@uef.fi
2 Arctic Centre, University of Lapland, Box 122, 90601 Rovaniemi, Finland

We studied land use and land cover changes over a 20-year period in two research areas located in Nenets autonomous districts Varandey oil field and in the Yamal-Nenets autonomous districts Bovanenkovo gas field in the Arctic Russia. These areas also serve as an important pastures of the Nenets reindeer herders. A number of impacts are associated with petroleum exploration and production which range from physical obstructions from roads, railways, and pipelines, as well as direct and indirect ecological impacts, such as changes in vegetation, soils and hydrology due to e.g. drilling, and infrastructure development. The effects vary from small-scale, only a few meters across, to several hectares. To conduct a multi-scale assessment of cumulative disturbances information on land use and habitat changes required a combination of remote sensing and detailed ground-truthing that embrace both scientific and local knowledge from indigenous herders and gas field workers. Database for satellite imagery analysis consist of Landsat MSS/TM/ETM7, SPOT, Terra ASTER VNIR and Quickbird-2 images. ERDAS Imagine 9.2 and ArcGIS 9.1 programs were used in data analysis. Land cover and land use was classified from years 1988, 1993, 1998, 2001, and 2009. NDVI's were calculated from years 1988, 1993, 1998 2000, 2001, 2004 and 2009. Change detection based on NDVI revealed most of disturbances occurred in the oil and gas field. Then a moving window algorithm with multiple scales was used to quantify and describe disturbance patterns from NDVI's. These layers were combined and disturbance level map was produced.

Snow cover monitoring using combined FORMOSAT satellite imaging, oblique view ground-based pictures and snow drills (East Loven glacier, Spitsbergen, Svalbard)

Dominique LAFFLY[1], Éric BERNARD[2], Jean-Michel FRIEDT[3], Gilles MARTIN[3], Christelle MARLIN[4], Madeleine GRISELIN[2]

1. Université de Toulouse, laboratoire GEODE UMR 5602 CNRS, 2. Université de Franche-Comté, laboratoire THÉMA UMR 6049 CNRS, 3. Université de Franche-Comté, laboratoire FEMTO-ST UMR 6174 CNRS, 4. Université de Paris-sud Orsay, laboratoire IDES UMR 8148 CNRS

In the frame of the Hydro-Sensor-FlOWS program (IPY #16), the East Loven glacier, located in Spitsbergen (78°N, 12°E, Norway) has been closely monitored during 4 years (2007 to 2010) in order to analyze at the basin scale (10 km2) and at various time scales (hour, day, month, year) the ice and snow mass-balance and their direct and indirect hydrological consequences.

For obvious cost reasons as well as due to poor weather including common heavy cloud cover, daily satellite imaging is not always accessible: only two monthly FORMOSAT data sets have been selected as representative of general snow cover. Nevertheless, fast events appear as significant in the ice and snow budget while being ignored by satellite based studies since the slower sampling rate is unable to observe such fast events.

In this program, satellite imagery is complemented with a set of ground based autonomous automated high resolution digital cameras. An average of 10 such devices were located in the glacier basin to gather oblique views of the whole glacier catchment at a sampling rate of 3 images per day. Beyond the significant qualitative information brought by the raw images in understanding the conditions in which scalar data were acquired (hydrological and weather data), quantitative analysis, and especially the comparison with satellite images, requires a geometrical conversion in order to provide an aerial point of the same pictures.

True photogrammetric processing is not feasible because of the low viewing angle, but Delaunay triangulation based mapping using a dense set of reference points provides the means for an accurate projection by applying a rubber sheeting algorithm. The main challenge lies in the lack of usable reference points on the glacier area. Therefore numerous GPS-located artificial marks (flags, skidoo tracks) were used to provide a set of anchoring points sufficiently dense for the projection of images. Following such a processing, numerous aerial-like images are recomposed from ground pictures. This set of new photos provides an image database useful for studying the snow dynamics over the glacier at a daily scale, not only qualitatively but also quantitatively with the computation of the equilibrium line altitude (ELA) defining the limit between snow covered and ice covered areas. Satellite images and ground pictures provide only a binary information concerning the presence or absence of snow and ice. This differentiation defines, for each point on the glacier surface, the melting coefficient which determines the amount of water coming from the melting of snow and ice in the hydrological equation of the glacier basin.
In parallel to image processing, systematic snow drills in 42 locations over the glacier area were performed to measure the snow thickness and its water equivalent. This dataset is interpolated over the glacier surface in order to generate melt balance maps for each drill campaign.

Both approaches, images and snow drills, are complementary in order to study the snow dynamics. This original approach is relevant for Arctic where the dynamics of processes is rarely observed and therefore is not easily quantified by classical methods.

Evaluation of AIS Reception in Arctic Regions From Space by using a Stratospheric Balloon Flight

Jesper A. Larsen, Jens Dalsgaard Nielsen*, Hans Peter Mortensen**, Ulrik Wilken Rasmussen**, Troels Laursen**, Jeppe Ledet-Pedersen***
{jal,jdn,hp000,wilken,trlau,jledet}@space.aau.dk
**: Assoc. Prof, **: Master students*
Department of Electronic Systems
Aalborg University, Denmark

Purpose:
Lately, there has been an increased interest in monitoring the maritime traffic around the island of Greenland, and since Greenland is part of the United Kingdom of Denmark, it is the Danish Maritime Safety Administrations (DMSA) duty to ensure the safety of the waters around Greenland. Traditionally, receiving and monitoring of AIS (Automatic Identification System) messages from ships has been done using buoys and ground stations which has range and coverage limitations due to the curvature of the earth. Therefore it is – in real life - impossible to obtain a good coverage at open sea and around Greenland. In the latest years, reception of AIS signals in space has had an increased interest, since AIS monitoring from a Low Earth Orbit (LEO) satellite overcomes limitations as depicted above. AAUSAT3 – a LEO student cubesat satellite from Aalborg University – shall investigate and evaluate reception of AIS signals in space.

Methodology:
To ensure success for AAUSAT3 a stratospheric balloon flight test was conducted in autumn 2009 from Esrange in Northern Sweden. The purpose was to test the two newly developed AIS systems as well as the AAUSAT3 prototype. The balloon flight, Bexus09, carried a fully functional prototype of the AAUSAT3 satellite. Throughout the duration of the balloon flight, which lasted approximately 3 hours at a height of 24 km, the satellite was operated as in orbit, with continuous downloads of data using the AAUSAT3 UHF system. Evaluation of the AIS systems was carried out by real time decoding of the received AIS information, as well as storage of sampled intermediate frequency AIS signal for later analysis.

Results:
A total of more than 100.000 AIS telegrams were received, and of those more than 25,000 were received with correct checksum. More than 2 GB of raw intermediate frequency AIS data was sampled and stored for further analysis and for development of a software based AIS decoder capable of better handling Doppler shifting and fading.
Based on the AIS estimators, it is possible to estimate, for each individual ship, exactly which AIS packages that were not received correctly. This provides a possibility of more advanced filtering techniques, which in turn would raise the successful reception rate.
A comparison with the available ground based data has shown, that there is a good coherence between the two data sets. Some ships were only present in the satellite AIS data and not in the base station AIS data, which is believed to be due to shadow effects near the coast.

Conclusion:
The balloon flight showed a very high quality and reliability of the AAUSAT3 prototype. The communication link, power-supply, AIS subsystems, and ground segment were fully functional during the entire flight and all mission objectives were fulfilled. It furthermore showed, that the received AIS signals were valid and showed a large correlation with the ground based reference data. Currently, AAUSAT3 is planned to be launched in the first half of 2011.

Ice-shelf surface undulations tracked using ICESat altimetry

Oliver John Marsh and Wolfgang Rack
oliver.marsh@pg.canterbury.ac.nz
Phone: +64 3 364 2987 ext.4982
Fax: +64 3 364 2197
Gateway Antarctica, Centre for Antarctic Studies and Research, University of Canterbury, Private Bag 4800, Christchurch, New Zealand.

Ice-shelf behaviour provides an important indication of the processes occurring at the boundary of marine-terminating ice sheets. It is particularly important to establish the rate of discharge across grounding-lines in order to calculate ice-sheet mass-balance and the potential contribution of grounded ice to sea-level rise. Here we present a method of using surface elevation data from the Ice, Cloud and Land Elevation Satellite (ICESat) to track horizontal movement of large-scale surface undulations on the Ross Ice Shelf, Antarctica. ICESat provides a high precision record of surface elevation, allowing surface undulations in the kilometre scale with amplitudes as small as 1m to be identified and tracked. Ten separate tracks obtained by ICESat between October 2004 and October 2008 in the region downstream of the grounding line of the Beardmore Glacier are compared, showing a strong inter-annual correlation between surface profiles. Distinct patterns in surface slope are observed in successive tracks and show the ice shelf moving steadily in a southerly direction. As the ICESat tracks do not always overlap exactly, a method to minimize the error caused by perpendicular track offsets is also discussed. Along-track velocity near the grounding line of the Beardmore Glacier is calculated to be 325 ± 15 m/yr which agrees well with published ground-based measurements. These initial results are encouraging and highlight the potential of altimetry as a method of estimating surface velocity on ice shelves which are apparently feature-less.

Application of different VHR satellite images for detailed mapping of forest spatial structure properties in the forest-tundra ecotone

Anton Novichikhin, BSc, and Olga Tutubalina, PhD*
Lomonosov Moscow State University, Faculty of Geography, Laboratory of Aerospace Methods
**novi-mail@mail.ru*

Tree height as well as crown coverage and distances between individual trees are among the criteria for definition of forest, forest-tundra and tundra zones in the forest-tundra ecotone. Definition of forest line, tree line and other borders in the transition area is important to study the structure of the forest-tundra ecotone. Estimation of these parameters requires very high resolution (VHR) remotely-sensed data (satellite or airborne multispectral images), because coarser imagery cannot provide the necessary detail.

The goal of this study is apply a local-focal object interpretation method for extraction of detailed information on spatial structure of forest, position of forest line and tree line in forest-tundra ecotone from the very high resolution (VHR) satellite imagery, using images from different sensors and for various areas of the Russian North.

We have analyzed several methods of obtaining detailed information about trees and integrated them into a complex image processing method. This is an enhanced shadow-vegetation method for automated processing of satellite images. It integrates local and focal image processing algorithms, and GIS-analysis of vector data.

We applied the method to several VHR satellite imageries (Quickbird, IKONOS and GeoEye) acquired in summer seasons in 2006-2009 for central and northern Kola Peninsula, Putorana Plateau and south-eastern Taimyr Peninsula.

Using our method we delineated single trees and shrubs in sparse forest in forest-tundra ecotone with an accuracy over 80% , as proved by detailed visual interpretation of validation transects. Tree heights have been calculated with 1.0 – 1.5 m accuracy using the shape-from-shadow technique. Tree line and forest line have been delineated. Tree canopy cover and distances between individuals have been calculated for various grid sizes, for further comparison with coarser imagery and development of multi-scale mapping approaches.

This study revealed that QuickBird satellite images is more suitable for detailed mapping of forest spatial structure properties than IKONOS or GeoEye images, due to a combination of good radiometric properties and spatial detail.

This research is part of PPS Arctic, the IPY project which investigates current status and past changes in the circum-arctic tree-line zone, as well as associated social and natural factors. The study is carried out in the Laboratory of Aerospace Methods of the Faculty of Geography, Lomonosov Moscow State University.

Characterisation of glacier facies with the Airborne Thematic Mapper

A. Pope and W.G. Rees*

Scott Polar Research Institute
Lensfield Road, University of Cambridge, Cambridge CB2 1ER, England

**Corresponding author; Email: ap556@cam.ac.uk*

Here we present preliminary work using multispectral imagery from the Airborne Thematic Mapper (ATM) to build a classification scheme for surface zones of arctic glaciers and icecaps constrained by recently collected data. Previous studies of snow spectral response indicates that the ATM's spectral and spatial resolution will allow for sensitivity in measuring the important but elusive firn line.

In design, the ATM is similar to Landsat's Enhanced Thematic Mapper Plus, but with key improvements to spatial (potential submeter vs. 30 m) and spectral (a near infrared band 0.91-1.05 μm) resolution. Published studies have used Landsat imagery and methods such as spectral band ratios, normalized indices, thresholding, principle component analysis, unsupervised classifications, supervised classification, and spectral mixing analysis to classify glacier surfaces. This research builds on these promising techniques with the application of new ATM data and potentially the integration of associated surface elevation data where appropriate with the goal of successfully and reliably identifying the extent of major glacier facies.

Compounding the already problematic issue of snow facies distinction, most published classification schemes suffer from a lack of reliable ground-truth to confirm identification of glacier facies based solely on remotely sensed data. Therefore, in addition to previously collected ATM data, associated fieldwork to Ny Ålesund, Svalbard was conducted during Summer 2010. The work presented here uses the collected in situ surface reflectance data to inform interpretation of ISODATA classification schemes, will provide end member points for spectral mixing studies, and gives a starting point from which to develop useful analysis strategies for remote imagery.

This research will lead to a reliable method for glacier facies identification using the Airborne Thematic Mapper, and hopefully a similar method for the related Landsat ETM+. In the future, accurate facies measurement will hopefully provide an effective mass balance proxy which facilitates global glacier monitoring, mass balance studies, water resource availability, and quantification of the largely uncertain contribution of small glaciers and icecaps to global sea level rise.

Assessment of ASTER Global Digital Elevation Model data for Arctic research

W G Rees
Scott Polar Research Institute
University of Cambridge
Lensfield Raod, Cambridge CB2 1ER
United Kingdom

The ASTER GDEM (Global Digital Elevation Model) product was released in 2009. It is generated automatically using all available images acquired by the ASTER instrument over land areas and is freely available. The standard data product consists of a one-degree tile, with a sample interval of 1 arcsecond, i.e. around 31 m in latitude and 31 cos (latitude) m in longitude. Heights are specified with a precision of 1 m and are references to the WGS84 geoid. The nominal vertical accuracy of the GDEM product is 7-14 m RMSE. It is thus comparable in many ways to the Shuttle Radar Topography Mission (SRTM) data that have been available since 2003. However, a major advantage of the GDEM product for polar research is its latitudinal coverage which, as a result of the high-inclination orbit of the Terra satellite, extends to around 7 degrees from the poles. This paper assesses the characteristics, accuracy and utility of GDEM data for arctic and subarctic research, by comparing it with DEMs constructed from airborne LiDAR and other sources from study sites in Russia, Norway and Iceland.

Automated spaceborne detection of degraded vegetation around Monchegorsk, Kola Peninsula, Russia.

W G Rees
Scott Polar Research Institute
University of Cambridge
Lensfield Raod, Cambridge CB2 1ER
United Kingdom

Nickel-smelting at the Severonikel' plant at Monchegorsk on the Kola Peninsula, Russia, is well known to have caused extensive damage to surrounding vegetation. This damage has been studied for many years, by the analysis of satellite imagery as well as through in situ investigations and combinations of the two approaches. In principle this allows for changes over time to be studied by comparing classifications of the extent of vegetation damage at different dates, but in practice there are a number of difficulties. The aim of the work described here is to develop a simple, minimally subjective, approach to quantifying the extent to which vegetation is disturbed from its natural state. The method that has been adopted is to relate the spatial variation of the normalised difference vegetation index (NDVI) of undisturbed vegetation to topographic variables, and then to identify significant departures from this relation. Based on the analysis of a Landsat ETM+ image from 2000, the NDVI of undisturbed vegetation within the study area varies between around 0.2 and 0.7. Most (63%) of the variance can be explained simply as a function of altitude, and the inclusion of topographic aspect increases the coefficient of determination to about 64%. The unexplained √variance in NDVI is around 0.1. Areas of disturbed vegetation are characterised by negative anomalies, i.e. the NDVI is lower than expected according to the model. In the most damaged areas these anomalies can be as large as -0.5.

NASA Airborne Science Program – IPY missions demonstrating remote sensing technologies for unmanned aircraft in the Arctic

Susan Schoenung, Senior Research Scientist, Bay Area Environmental Research Institute, NASA Ames Research Center, Moffett Field, CA 94035

Randal Albertson, Deputy Director, NASA Airborne Science Program, NASA Dryden Flight Research Center, Edward AFB, CA 93523

In support of the International Polar Year, NASA's Airborne Science Program funded the development and demonstration of five autonomous airborne remote sensing systems for Arctic science. All flew successful missions during the last year. All five missions, instruments and aircraft systems, along with lessons learned and the science results of the missions, will be described in this paper.

The first of these was the "Sea Ice Roughness as an Indicator of Fundamental Changes in the Arctic Ice Cover: Observations, Monitoring, and Relationships to Environmental Factors. This research effort, led by the University of Colorado, combined satellite data analysis, modeling, and aircraft observations. The airborne experiment, "Characteristics of Arctic Sea Ice Experiment" (CASIE) flew from Svalbard, Norway in July 2009. CASIE's role in this project was to provide very detailed information on ice conditions by using a mid-size unmanned aircraft (NASA's SIERRA) that can fly long distances at low altitudes – a job that can be difficult and dangerous for large, manned aircraft, especially in the harsh Arctic environment. The primary payload consisted of two LIDARS and a C-Band SAR for providing information on ice surface roughness and topography, thickness, reflectance, and age.

The second and third missions took place in Greenland in May and June 2009. These were Interferometric SAR measurements of the glaciers and ice topography of Greenland. The missions were performed using NASA's G-III aircraft carrying the JPL Unmanned Aerial Vehicle Synthetic Aperture Radar (UAVSAR) system, a UAS surrogate. This was the first deployment for the G-III, a challenging mission to measure ice dynamics in Greenland and Iceland using first a Ka-Band and then an L-Band synthetic aperture radar. The deployment included two weeks of data collection with the Ka-Band radar, called GLISTIN (Glacier and Land Ice Surface Topography INterferometer) over the Jacobshaven Glacier and along a transect to High Point (at 10,000 ft, the highest point in Greenland), allowing observations of a variety of snow and ice conditions. One flight was a coordinated flight with the Airborne Topographic Mapper (ATM) sensor aboard the NASA P-3. Early results revealed that the Jacobshaven glacier calved approximately 1.5km over a 6-day interval. Flights with the second pod and L-Band radar included the "Top of the World" over the Greenland glaciers and ice sheet.

Finally, as part of NASA's Global Hawk Pacific (GloPac) mission, two established remote sensing instruments were reconfigured to fly unattended on the NASA high altitude, long endurance Global Hawk UAS. These were NASA Goddard's Cloud Physics Lidar (CPL) and JPL's Microwave Temperature Profiler (MTP). The CPL is a backscatter LIDAR for high-resolution profiling of clouds and aerosols, and the MTP is a passive microwave radiometer for making measurements of O2 thermal emissions. Among the science objectives for the flights toward the north pole were the following: 1) Sample arctic environment: polar vortex air chemistry, ice surface, clouds and aerosols, 2) Map mid-latitude/polar mixing, and filamentation, and 3) Under-fly the NASA Aura satellite in the polar region. These objectives were accomplished during the April 2010 GloPac mission.

Advanced approach to mapping human impact on vegetation of the European North

E. Shipigina, G. Rees
Scott Polar Research Institute, University of Cambridge, UK
es377@cam.ac.uk, wgr2@cam.ac.uk

Northern vegetation is an essential element in the formation of the global climate, heat balance, ocean circulation etc. Wide political and economical interests to the northern regions have led to the destruction and disturbance of the vegetation by different types of human impact: industrial air emissions, fire, forest logging, grazing, oil-gas development and industrial settlement infrastructure development. Environmental hotspots have appeared in places where human impact is most extreme. For example, heavy metal pollutions and sulphur dioxide emissions from the copper-nickel smelter in Monchegorsk, Russia, or reindeer grazing in Lapland, Finland, have led to disturbed vegetation in these areas. The level of disturbance is reflected in the vegetation structure on a local scale and the dynamic of the forest-tundra boundary position on a regional and global scales.

Our research is focused on developing automated remote sensing techniques for environmental monitoring of any human impact on vegetation utilizing multi-temporal images. The study area is close to forest-tundra boundary and stretches across the northern regions of Norway, Sweden, Finland and European Russia. During the current development stage the technique is being tested on a selection of test areas with high quality field data. The research is based around a large number of multi-temporal Landsat images from free Internet archives and is driven by algorithms implemented within the R-project open source framework. Time spent on manual image interpretation, quality of this interpretation and the objectiveness and reproducibility of the results are the major factors in case of working with a large set of images. The R scripting framework allows batch processing of image meta-data, the application of total atmospheric correction taking into account the spectral reflectance of pixels all in a matter of minutes. Subsequently, a supervised classification of data within our outside of the test areas is carried out within the same framework using support vector machines (SVM) or any other method of choice.

A preliminary assessment of image interpretations by SVM demonstrates very accurate separation of classes confirmed by the field data from the test areas. The method uses data from across a wide area, covered through many images, thus giving confidence for the quality of prediction outside the test areas where little or no field data is available.

The open source nature of the R-framework makes sharing scripts straightforward enabling wider access to knowledge and tools.

Surface based microwave radiometer measurements in sub-arctic tundra and boreal forest environments: November 2009 to April 2010

Peter Toose[1], Chris Derksen[1], Arvids Silis[1], Alain Royer[2], Alexandre Langlois[2], Nick Rutter[3] Joshua King[4], Richard Kelly[4] and Claude Duguay[4]

1. Environment Canada, Climate Research Division, Toronto, Ontario, Canada
2. Université de Sherbrooke, Sherbrooke, Québec, Canada
3. Northumbria University, Newcastle upon Tyne, United Kingdom
4. University of Waterloo, Waterloo, Ontario, Canada

Sled-mounted microwave radiometers were used to monitor the temporal evolution of brightness temperatures over snow covered ground and frozen lakes at 6.9, 19, 37 and 89 GHz (vertical and horizontal polarizations) in a sub-arctic environment. Data were collected during the Canadian CoReH20 Snow and Ice Experiment (Can-CSI) between November 2009 and April 2010 at multiple sites along the forest/tundra transition near Churchill, Manitoba, Canada. Personnel were present for the entire winter, conducting weekly snow and lake ice surveys. During 2 week periods each month, intensive microwave radiometer measurements were also acquired. The snow survey information was recorded to help interpret changes in brightness temperatures and included the following information: snow depth, density, water equivalent, grain size (physical dimensions and specific surface area), stratigraphy, snowpack temperature profiles and snow dielectrics. Lake ice measurements included ice thickness, type, and stratigraphy (bubble type and density).

Two different microwave radiometer sampling strategies were employed during this field campaign. The first strategy was to establish a set of 'undisturbed' radiometer measurement sites in different land covers that could be re-visited throughout the winter without disturbing the snowpack. Only snow depths were recorded at the undisturbed sites, with further snow information obtained in adjacent plots. Repeated measurements at the undisturbed sites throughout the season allowed for changes in brightness temperatures to be interpreted as physical changes in the snowpack, rather than changes in the surrounding environment. At the end of the season, a snow trench and/or ice core was excavated at each undisturbed site to document the snowpack and ice characteristics in both a vertical and horizontal plane. The second sampling strategy was to take measurements at 'disturbed' sites close to the undisturbed locations, where the radiometer measurements were acquired first and then detailed snow and/or lake ice measurements were made within the field of view of the 19 and 37GHz radiometers. The disturbed sampling strategy was used throughout the season to relate observed brightness temperatures with a variety of well documented known snowpack properties and/or lake ice structure.

The sampling strategies employed during this campaign have produced a unique time series of detailed snow, ice, and brightness temperature information which will better our understanding of the seasonal metamorphosis of tundra and boreal forest snowpacks over an entire winter, and how these physical changes influence observed brightness temperatures at the local scale. This knowledge will improve current research efforts to develop snow water equivalent retrieval algorithms specific to arctic and sub-arctic regions using brightness temperatures from passive microwave radiometers on board both past and present spaceborne platforms. This presentation will provide an overview of the brightness temperature time series in the context of the physical snow and ice measurements, and outline ongoing efforts to couple simulations with physical snow and radiative transfer models.

New Methods of Mapping Sea Ice Thickness Using Waves

P. Wadhams (1) and F. Parmiggiani (2)
(1) Dept. of Applied Mathematics and Theoretical Physics, University of Cambridge, Cambridge CB3 0WA, UK. (2) ISAC-CNR, Bologna, Italy

Two new methods of mapping ice thickness have been recently developed and tested, both making use of the dispersion relation of ocean waves in ice of radically different types. In frazil-pancake ice, a young ice type in which cakes less than 5 m across float in a suspension of individual ice crystals, the propagation of waves has been successfully modelled by treating the ice layer as a highly viscous fluid. The model predicts a shortening of wavelengths within the ice. Two-dimensional Fourier analysis of successive SAR subscenes to track the directional spectrum of a wave field as it enters an ice edge shows that waves do indeed shorten within the ice, and the change has been successfully used to predict the thickness of the frazil-pancake layer. Concurrent shipborne sampling in the Antarctic has shown that the method is accurate, and we now propose its use throughout the important frazil-pancake regimes in the world ocean (Antarctic circumpolar ice edge zone, Greenland Sea, Bering Sea and others). A radically different type of dispersion occurs when ocean waves enter the continuous icefields of the central Arctic, when they couple with the elastic ice cover to propagate as a flexural-gravity wave. A two-axis tiltmeter array has been used to measure the resulting change in the dispersion relation for long ocean swell (15-30 s) originating from storms in the Greenland Sea. The dispersion relation is slightly different from swell in the open ocean, so if two such arrays are placed a substantial distance (100s of km) apart and used to observe the changing wave period of arrivals from a given storm, the time delay between the arrival of the same frequency at two sites gives the dispersion, and hence the modal ice thickness along the great circle route connecting the arrays. The two quite different methods thus share the use of ocean wave dispersion to infer sea ice thickness by remote sensing.

PINRO Airborne Research on Study of the White Sea Harp Seal Population Pup Production Abundance

Vladimir B. Zabavnikov, Ilias N. Shafikov;

The N.M. Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO);
Post address: 6, Knipovich Street, Murmansk, 183038, Russia
Phone: (+7)-815-2-47-25-72, fax: (+7)-815-2-47-33-31,
e-mail: ltei@pinro.ru;

PINRO has a long historical experience for airborne research on study of the White Sea harp seal population pup production abundance. The first research this direction was carried out in 1928. From this time to today gone way from simple visual observations from aircraft to using of modern methods and technologies where apply remote sensing equipments which work in optical and infrared (IR) ranges of electromagnetic wavelengths. This case the main research biological object is only one and it is pup production of the White Sea harp seal population. Under that modern PINRO method and technology for study above biological object was named as multispectral.

During ten last years for considered multistectral aerial research used two engines aircraft Antonov-26 (An-26) named “Arktika”. On board this aircraft installed and operated following remote sensing equipment:
standard digital photo – and video cameras («Nikon D1X» and “Panasonic”, accordingly),
IR-scanner “Malakhit” which was worked, created and adopted for considered aerial research specially.

Airborne research on study of the White Sea harp seal population pup production abundance on base of knowledge of harp seal biology carry out during March first half but no later than March 22. The main area of research is the White Sea and adjacent water of the Barents Sea, the first south-east part. All research flights carry out along basic transects which are oriented along longitudes with distance between its no more than 10 km from flight altitude no less than 200 m, standard is 250-300 m. Each research flight transect begins and finishes on ice edge or coastal line.

When considered research flights are finished then starts optical and IR-images special processing and analyze where use approaches and methods which were worked and created by PINRO. After that makes special calculation on total pup production abundance which use in future for calculation of the White Sea harp seal population stock size. These results present in Joint NAFO/ICES Working Group on Harp and Hooded Seals where prepare recommendations and advices on rational of North-East Atlantic harp seal stocks catch including their influence on fisheries.

For example, at present the White Sea harp seal stock has stable low level condition in the first as his pup production abundance be on modern low level, in 2005 it was 122 700, in 2008 - 123 100, and in 2009 - 156 600. Between 2005 – 2008 during two years airborne research on study of the White Sea harp seal population pup production abundance under above main principles did not carry out on logistical reasons. In 2005 was recorded the lowest modern level of pup production abundance. Under carried out additional and special research the main reason that was climatic changes in the Russian Arctic west part where was fixed warmer that cased decrease of ice cover area and ice season duration in comparing with end of 1990-s years and 2000-s beginning when was recorded the White Sea harp seal population pup production modern maximum.

Research of Feeding Mackerel in the Norwegian Sea and Her Environmental Conditions with Using of Airborne Remote Sensing Methods.

Vladimir B. Zabavnikov, Sergey A. Egorov;

The N.M. Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO);
Post address: 6, Knipovich Street, Murmansk, 183038, Russia;
Proposed presenter: Vladimir B. Zabavnikov
Phone: (+7)-815-2-47-25-72, fax: (+7)-815-2-47-33-31,
e-mail: <ltei@pinro.ru>

In modern stage PINRO carries out regular research of feeding mackerel (schools distribution and their biomass calculation) including study of her environmental conditions in the Norwegian Sea with using of airborne remote sensing methods which is part of Institute ecosystem survey this area. Traditionally considered research direction carries out onboard special equipped two engine aircraft Antonov-26 (An-26) named “Arktika”. Here use airborne remote sensing equipment which work in optical, infrared (IR) and very high frequency (VHF) electromagnetic wavelength ranges.

The main principle this research is data collection about feeding mackerel schools (distribution and numbers) including some their parameters and environmental oceanographic conditions. All rough data collect simultaneously in real time and position, and its input to aircraft onboard computer. Considered airborne researches carry out along flight tracks with distance between its no more than 30 nautical miles from flight altitude no less than 120 m, standard is 150-200 m. These tracks oriented along direction where record oceanographic parameters maximum space change under long-term data (climatic data). Considered airborne research carry out only in the case if on area it simultaneously observe following meteorological conditions no less than 75% this area:
cloud cover low edge – no less than 100 m,
surface wind speed – no more than 8 m/s,
- lack of haze, fogs, and other atmospheric phenomena (shower rain, snow, drizzle and so-on).

Here use following airborne remote sensing equipment:
1. IR-radiometer and scanner. IR-radiometer uses for sea surface temperature (SST) measurements along flight track. On base these rough data prepares map of SST space distribution where use of standard methods, principles and approach for extrapolation, interpolation and interpretation. IR-scanner allows to get sea surface thermal images in swath no less than 144 m which dependent on flight altitude.
2. Optical equipment - LIDAR. It allows to get rough data along flight track about presence of mackerel schools including information about their vertical parameters and also information about oceanographic parameters (transparency, picknokline depth – both in real physical units; presence and concentration of plankton subsurface layers and surface initial biological productivity – both in relative units). After research flight all above data map.
3. VHF – equipment, it is synthetic aperture radar (SAR). SAR uses for collecting rough data as SAR-images about presence on sea surface of feeding mackerel schools, hydrodynamics inhomogeneous and its space structure in swath no less than 2 km which dependent on flight altitude. SAR is all weather remote sensing equipment in contrast of IR equipments and LIDAR.
4. Standard photo- and video cameras. Its use for documentation of difference effects and phenomena on sea surface.

Also standard visual observations carry out from aircraft both side though special convex windows, which named “blisters” where record fish schools, oceanographic phenomena, marine mammals and sea birds. Here swath is equal doubled flight altitude.

Thus considered airborne research is complex and has ecosystem approach. After flight all data has special processing and present in GIS adopted map.

During presentation will be present many examples of considered research.

Poster Presentation

Remote Sensing of Permafrost-related aspects of the Alaska North Slope region.

Poul Christoffersen, Julian Dowdeswell, Toby Benham and Ruth Mugford
Scott Polar Research Institute, University of Cambridge.

A useful technique to aid assessment of the state of permafrost on the North Slope of Alaska is automatic mapping of thaw lakes, which tend to form gradually and drain rapidly. We mapped tens of thousands of thaw lakes (predominantly from Landsat data) in six selected areas on the central part of the Alaskan coastal plain. We found that most lakes were becoming progressively smaller in 1978-1990, larger in 1990-2005 and smaller again in 2005-2009. Published studies are based on fewer records and report mainly lake diminishment. Our study reveals very large interannual variations of thaw lakes. The declining lake extent coincides with an increase in mean annual temperature in Barrow from -14°C in 1975 to -12°C in 1990. However, a distinct increase of thaw lakes in 2005 was caused by high rates of precipitation. Mean annual air temperature in Barrow is currently close -10°C and summer temperatures are approaching +5°C on average. It is possible that the extent of thaw lakes will decline as the Arctic warms, but it is also possible that increased precipitation under warmer climate will be able to sustain high lake levels. Liquid water has a high heat capacity and is able to effectively melt permafrost. Surface hydrological impacts on permafrost will be assessed in a forthcoming numerical modelling phase.

Poster Presentation

A first vegetation map of the Antarctic Peninsula as a baseline for measuring future change

Peter Fretwell, Adrian Fox, and Christian Hasselwimmer: British Antarctic Survey

Climate records at research stations show that the Antarctic Peninsula region is one of the fastest warming areas in the southern hemisphere (Vaughan 2006). Vegetation in the area is currently very sparse, both in density and species diversity. It consists mainly of mosses and lichens with flowering plants limited to a few species of grasses in favourable locations (Smith 1996).

However, changes in regional climate leading to a longer growing season and/or greater availability of free water are likely to impact on the vegetation through: increases in local density and verdancy; changes in vegetation distribution through colonisation of new areas previously outside the climatic range through aspect or latitude, and incursion of alien species (Convey 2003, 2006; Frenot et al. 2005).

At present there is no map of vegetation distribution on the Antarctic Peninsula because previous vegetation research has concentrated on detailed sampling to characterise the vegetation at widely distributed sample sites rather than synoptic mapping (Peat et al. 2007).

The size (~420,000 km2) and inaccessible nature of the Peninsula have limited the effectiveness of ground-based survey methods. To overcome these problems and provide a synoptic, repeatable method of mapping/monitoring vegetation cover, the British Antarctic Survey (BAS) has been investigating the potential of a variety of remote sensing techniques.

This poster describes work at the BAS using NDVI analysis of Landsat ETM+ images, acquired as part of the Landsat Image Mosaic of Antarctica (LIMA) project (2007), to develop the first vegetation map of the Antarctic Peninsula region. This is important as a baseline for measuring any future changes. The poster comprises three sections:

Firstly the poster explains the image analyses used to identify the very sparse vegetation from 15 m resolution Landsat imagery (Fretwell et al, in press). Next the remotely sensed analyses are validated by field reflectance spectroscopy, which has established reflectance properties of the different vegetation types at a number of point locations (Haselwimmer and Fretwell, 2009). Finally high resolution false-colour, near-infra-red aerial photography has been used to calibrate the spatial response and areal vegetation coverage in sample areas.

Future proposed research includes the analysis and calibration of very high resolution satellite imagery and acquisition of hyperspectral reflectance and thermal data over important vegetation sites on the west coast of Graham Land during the 2010/11 field season.

Poster Presentation

Impacts and Implications of Increased Fire in Tundra Regions of North America

Nancy H.F. French,
Senior Scientist,
Michigan Tech Research Institute,
3600 Green Ct., Suite 100
Ann Arbor, Michigan 48105 USA
Ph: +1-734-913-6844
Fax: +1-734-913-6880
nancy.french@mtu.edu

Tatiana Loboda,
Research Assistant Professor
University of Maryland,
Department of Geography
2181 LeFrak Hall,
College Park, Maryland 20742 USA

A new NASA-funded activity has just begun to assess the impacts of a changing climate on tundra fire and the implications for tundra ecosystem services vulnerable to a changing fire regime. In the three years of this project, we plan to investigate the influence of climate change in the Arctic on fire occurrence and fire effects in the tundra ecoregions of North America (NA) and address the question: If fire increases in landscapes where fire is neither currently nor historically of great importance, what impacts will this have on the ecosystem services? Current satellite-based methods for mapping fire at northern latitudes are focused on algorithms tuned to forested landscapes rather than treeless tundra types. Therefore, our current accounting of recent fire for the circumpolar arctic is not complete. Fire regime is most likely changing, and will be changing quickly since fire is strongly driven by climate. Large, extreme fire events such as the 2007 Anaktuvuk fire have the potential to become more numerous as fire season lengthens and climate conditions become more favorable to fire spread. We intend to connect with current research efforts at the Anaktuvuk site as well as studying fire locations across NA. By looking at fire across the region, the role of fire in shaping ecosystem conditions can be better understood if fire regime changes in Arctic NA.

As our first step, we plan to improve maps of past fire using remote sensing-based techniques for fire mapping but “tuned” to detect fires in treeless, Arctic landscapes. Once we have compiled some sites to look at, surface conditions following fire will be assessed in the field and from remote sensing. We will use the acquired knowledge to drive a fire occurrence model fine-tuned to ecosystem specifics of Arctic NA. We also plan to apply existing climate models within a framework of fire occurrence modeling to develop future fire occurrence scenarios.

The fire regime information for the past into the future will be used to investigate the possible implications of climate change-induced fire regime change. Influences of particular interest are related to impacts on systems specifically vulnerable to climate change and/or disturbance. The factors we will investigate are: 1) changes to surface hydrology; 2) implications for carbon cycling and sequestration; 3) influences on energy balance (greenhouse gases and albedo); and 4) impacts to wildlife land use, such as caribou forage conditions.

Poster Presentation

Lithological mapping on the Antarctic Peninsula using Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data

C.E. Haselwimmer(1,2), T.R. Riley(1), and J.G. Liu(2)*
(1) British Antarctic Survey, High Cross, Madingley Road, Cambridge, CB3 OET
(2) Department of Earth Science and Engineering, Imperial College London, SW7 2AZ
**Corresponding author: chha@bas.ac.uk*

The Antarctic Peninsula is larger than the UK and with limited geological mapping campaigns since the 1940s significant gaps in coverage remain, particularly in areas where access is difficult. Remote sensing offers potential for improving geological mapping on the peninsula but has so far not been used for these purposes. A summary of current research by the British Antarctic Survey on the use of ASTER data for lithological mapping of predominantly calc-alkaline subduction-related igneous rocks exposed on the Antarctic Peninsula is presented. The research encompassed lithological mapping of four case study areas selected to provide an appropriate test of the potential of ASTER for mapping typical Antarctic Peninsula rock types and under varying physiographic conditions. Spectral image processing of ASTER reflectance and thermal emission data employed qualitative enhancement procedures aswell as the matched filter (MF) spectral mapping method. Analysis of the ASTER data was supported by rock reflectance spectroscopy, processing of Hyperion hyperspectral data, thin section petrography, analysic of geochemical data for certain volcanic rocks, and limited fieldwork. The research demonstrates that although outcrop is limited in the polar context, weathering effects and vegetation cover do not cause significant problems for lithological mapping. ASTER provides a range of lithologic information enabling validation of inferred field mapping and new observations of unmapped geology in the study areas. Granitoids and silicic volcanic rocks display distinctive spectral properties and are newly identified from unmapped parts of the Oscar II, Foyn, and Lassiter coasts. Areas of localised alteration in these rocks are readily discriminated based on the distinctive absorption features of alteration mineral assemblages. ASTER is less successful at discriminating intermediate-mafic igneous, sedimentary and metamorphic lithologies that display more ambiguous spectral features. For these rocks lithological mapping is strongly reliant on existing field observations to resolve ambigious results. The research shows that although ASTER is limited in its ability to uniquely discriminate different rock types it can provide important lithological information in support of geological mapping on the Antarctic Peninsula.

Poster Presentation

Landslide activity and tundra regeneration on Yamal Peninsula, Russia, observed from satellite image time series

Kumpula T[1], Tanskanen, A[1] & B.C. Forbes[2]
1 Department of Geography and history, University of Eastern Finland, Yliopistonkatu 7, 80101 Joensuu, Finland; timo.kumpula@uef.fi
2 Arctic Centre, University of Lapland, Box 122, 90601 Rovaniemi, Finland

We have studied landslide peak which occurred in Bovanenkovo region in Central Yamal peninsula of late 1980's. According to Leibman (1995) increased precipitation caused this event in summer 1989. Database of satellite images was collected to follow landslide activity 1969-2009. Imagery used were CORONA, Landsat MSS/TM/ETM7, SPOT, Terra ASTER VNIR and Quickbird-2 images from years 1969, 1988, 1993, 1998, 2001, 2004 and 2009. Fresh landslide surface reflects similar to other bare surfaces and differentiating landslide from sand, bare soil patches, river and lake banks etc. from satellite imagery is a demanding task and in image classification they tend to mix between each other. Field data was collected from several years and sites. Earliest and most detailed data is from 1993 from large landslide field close to Vaschiny dachi camp. More recent data was collected in 2004 and 2005.

CORONA image from 1969 is used as a starting date of analysis. Landsat TM image dated from 1988 just before the main landslide event in 1989. This image was compared to SPOT (1993,1998), Landsat ETM+ (1999, 2001), Landsat TM (2009) and Terra ASTER VNIR (2001) images to detect occurred landslides. Quickbird-2 (2004) (QB) images were used to help the interpretation of the SPOT and Landsat images and to detect small scale landslides (< 1 ha). All identified landslides were saved into a GIS database as points and the boundaries of the landslides were digitized. From SPOT, Landsat, ASTER and Quickbird-2 images bare soil were classified both with unsupervised and supervised methods. Digitized landslide polygons were used to differentiate land slide from other bare soil surfaces. Characteristic spectral reflectance of landslides was estimated and images were reclassified.

Change detection using NDVI verified well larger scale landslides, but was not generally reliable enough alone to estimate the occurrance and areas of the landslides. Errors caused by nearby Bovanenkovo gas fields anthropogenic disturbances like roads, quarriers and other infrastructure around the gas field were masked out with buffers. In data analysis we used ERDAS Imagine 9.2 and ArcGIS 9.1. Final estimation of landslide occurrence was made with combined visual interpretations, change detection (NDVI), image classifications. Totally in the study area there were about 450 landslides.

Poster Presentation

Linear spectral mixture modelling of arctic vegetation using ground spectroradiometer

A. Mikheeva, PhD Candidate, A. Novichikhin, BSc, O. Tutubalina, PhD*
M.V. Lomonosov Moscow State University, Faculty of Geography, Laboratory of Aerospace Methods
** corresponding author, e-mail to: Arvin2@yandex.ru*

There are many techniques of spectral unmixing that can be applied to medium-resolution data from sensors such as Landsat TM/ETM+ or Terra ASTER for mapping large spatial extents. Linear spectral unmixing model is the most abstractive and most simple one, but it does not provide for high accuracy of endmember extraction. If the endmember reflectances are similar, the same summary reflectance can originate from mixtures of different spectral end members with different abundancies.

The main purpose of the study is to describe how the reflectance of mixture of vegetation, shadows and non-vegetation objects is formed, on the basis of ground-level data. We aim to answer whether it is linear or non-linear sum of reflectances, to find out whether we can use the linear mixture model to upscale from detailed imagery of arctic vegetation to coarser imagery, and define the accuracy of such modelling.

Using a 4-band SkyInstruments SpectroSense+ ground spectroradiometer, we modelled various multispectral image pixels as mixtures of end-member spectra. We measured samples of several types of fruticose ichens, rocks, shrubs, *Betula tortuosa* and *Pinus sylvestris*. Samples were assembled manually in adjacent hexagonal frames filling the circular field-of -view of the spectroradiometer. The components presented in the mixtures were changed gradually from 0% to 100% at 10% interval. Also we changed their spatial distribution from regular to random.

Using the spectra of pure end-members in the model, it was possible to decompose the spectral information of all mixtures into several components, giving their percentage cover within every pixel. We investigated how the mixture on the ground level depends on the endmember percent coverage, their spatial distribution and vertical structure. This can be used as a tool for spectral mixture analysis to help to upscale from high resolution to medium resolution multispectral imagery. It can also be used for the more general task of finding the best mixture model that fits a given data set.

This research is part of PPS Arctic, the IPY project which investigates current status and past changes in the circum-arctic tree-line zone, as well as associated social and natural factors. The study is carried out in the Laboratory of Aerospace Methods of the Faculty of Geography, M.V. Lomonosov Moscow State University.

Poster Presentation

Spatial structure map for tundra-taiga ecosystems in Tuliok river valley based on classification of QuickBird satellite imagery and GIS analysis

Anton Novichikhin, BSc, and Anna Mikheeva, PhD student*
Lomonosov Moscow State University, Faculty of Geography, Laboratory of Aerospace Methods
**novi-mail@mail.ru*

Tundra-taiga transition zone is a dynamic system, which indicates direction and intensity of global processes occurred in northern territories. It extends over large territories and if often inaccessible for complex field studies. Interpretation of remotely sensed data such as satellite or airborne imagery is a way to analyze present condition and past changes of ecotone.

Image classification techniques provide classified information about ecosystem components, and provide a base for ecosystems mapping. Level of detail of interpretation depends on spatial and spectral resolution of data. Mixture of different components may be estimated using spectral unmixing techniques applied to hyperspectral or multispectral middle resolution satellite imagery (e.g. Hyperion, Terra ASTER, Landsat e.t.c) but this techniques require spectral libraries collection and also could not provide reliable accuracy of components abundance.

The lack of spectral information in very high resolution imagery is balanced with texture information and shadow effects. They consistently increase their weight when spatial resolution became more detail. It is possible to interpret these images and then to mix different components on a selected grid-size and then to select different types of ecosystems based on components abundances.

We used a QuickBird multispectral image acquired on 28 June 2006 for a study area in the Tuliok River valley, Khibiny Mountains, Kola Peninsula, Russia, IHS-transformation of this image and a texture index of standard deviation to classify it to 10 classes (shadowed and lit classes for stones, lichens, shrubs, deciduous and coniferous trees). Classes then were translated to abundances for 15m grid-size which corresponds to spatial resolution of ASTER images. Abundances were used for ecosystems selection and an ecosystems map for Tuliok valley generation.

This map will be further used in conjunction with ASTER imagery to enhance the accuracy of its classification using spectral unmixing techniques.

This research is part of PPS Arctic, the IPY project which investigates current status and past changes in the circum-arctic tree-line zone, as well as associated social and natural factors. The study is carried out in the Laboratory of Aerospace Methods of the Faculty of Geography, Lomonosov Moscow State University.

Poster Presentation

Recent Changes to Langjökull, Iceland: Integrating airborne LiDAR and Landsat imagery

A. Pope[1,], W.G. Rees[1], I.C. Willis[1], N.S. Arnold[1], F. Pálsson[2], and R. Hodgkins[3]*

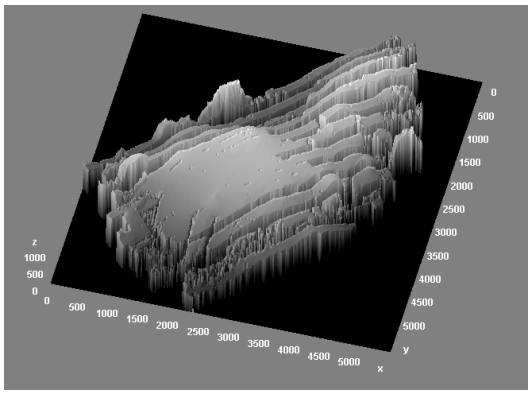
1 Scott Polar Research Institute, Lensfield Road, University of Cambridge, Cambridge CB2 1ER, England
2 Institute of Earth Sciences, University of Iceland, Sturlagata 7, IS-101 Reykjavik, Iceland
3 Department of Geography, Loughborough University, Loughborough LE11 3TU, England

**Corresponding author; Email: ap556@cam.ac.uk*

Langjökull, Iceland's second largest icecap (~950 km2), was the subject of an incomplete airborne LiDAR survey in August 2007 (Figure 1). This study investigates and evaluates the application of photoclinometry which employs visible light imagery (here, Landsat ETM+ band 4) to interpolate unmeasured sections of this fragmented data set. A complete digital elevation model (DEM) of Langjökull was produced (Figure 2), and photoclinometry was determined to be a satisfactory and robust technique for topographic interpolation (RMS error = 3.4 m over 3 km). Future cryospheric applications of photoclinometry can ensure optimal results by focusing on the consistent ability of the imager to accurately represent low contrast surfaces, the solar position in available imagery, and the appropriateness of the terrain for this technique.

Using the completed DEM of Langjökull for summer 2007 and a previously prepared corresponding 1997 data set, Langjökull was found to have an annual mass balance of -1.10 ± 0.09 m yr-1 w.e., which confirms published predictions that Langjökull will likely disappear within the next 200 years. Visual inspection and tracing of Landsat images showed a recession of -3.4 ± 2.5 km2 yr-1 from 1994 to 2007. The new 2007 DEM allowed for clear visualization of strong recession on several Langjökull outlets as well as interior mass loss and terminus advance witnessing to the 1998 surge event of outlet Hagafellsjökull Eystri. In addition, slight interior elevation increase and anti-correlated mass loss and terminal retreat potentially indicate a future surge of outlet Hagafellsjökull Vestari.

The technological and glaciological information put forward in this study provides a method for innovative cryospheric research, presents a much needed benchmark and update on the state of Langjökull, and ultimately facilitates and encourages continued monitoring of important smaller ice masses.



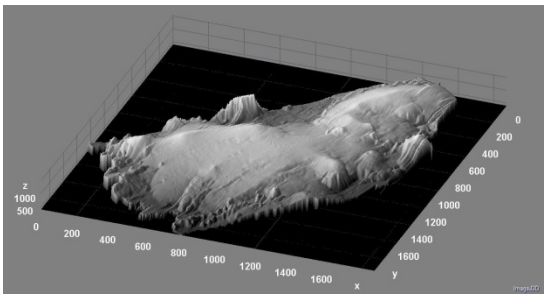


Figure 1 (left). Shaded 3D image of LiDAR values collected over Langjökull
Figure 2 (right). Shaded 3D image of photoclinometry-interpolated Langjökull DEM

Poster Presentation

Glacier displacement of Comfortlessbreen, Svalbard, estimated by differential SAR interferometry (DInSAR) with digital elevation model (DEM)

Nora Jennifer Schneevoigt[1], Wiley Bogren[2,1], Monica Sund[3,1], Dan Johan Weydahl[4], Andreas Kääb[1]*

[1] Department of Geosciences, University of Oslo, PO Box 1047 Blindern, N-0316 Oslo, Norway
[2] Norwegian Institute for Air Research (NILU), PO Box 100, N-2027 Kjeller, Norway
[3] The University Centre in Svalbard (UNIS), PO Box 156, N-9171 Longyearbyen, Norway
[4] Norwegian Defence Research Establishment, Land and Air Systems Division,PO Box 25, N-2027 Kjeller, Norway

***** Corresponding author. Postal address: Department of Geosciences, University of Oslo, PO Box 1047 Blindern, N-0316 Oslo, Norway. E-mail address: njs@geo.uio.no, Tel.: +47 - 228 57318, Fax: +47 - 228 54215*

This study focuses on glacier dynamics, aiming at a reconstruction of glacier flow with synthetic aperture radar (SAR) data. Glacier displacement in line of sight of a SAR satellite sensor can be estimated by differentiation of the fringe structures in two SAR interferograms. Differential synthetic aperture radar interferometry (DInSAR) is used to separate the phase contributions from topography and movement by subtracting either phase from the other. Hence pure terrain displacement can be derived without residual height information in it. However, fast movements appear blurred in radar applications due to decorrelation or coherence loss.

Comfortlessbreen, a currently surging glacier, flows predominantly in line-of-sight direction with respect to the European Remote Sensing satellites ERS 1 and ERS 2. Four C-band SAR scenes of the 1-day repeat-pass tandem mission of the ERS sensors from spring 1996 were selected because of their high coherence. In 2-pass DInSAR, a reference interferogram with phase differences corresponding to surface topography is simulated based on a digital elevation model (DEM) in radar geometry. A SPOT (Satéllite Pour l'Observation de la Terre) SPIRIT digital elevation model (DEM) from 2007 was used for this effect. Maximum horizontal displacements of around 25 cm/d in ground range direction can be detected at the glacier terminus, while less than 3 cm/d characterise most of the upper portions of Comfortlessbreen in 1996.